USDA United States Department of Agriculture

Rocky Mountain Research Station

Science You Can Use Bulletin

MAY/JUNE 2021 | Issue 48

# **Forest Understories Became the Story:** Lynx, Bark Beetle Mortality, and Salvage Logging

In 1999, when the first reintroduced Canada lynx explored their new home in the Rio Grande National Forest's San Juan Mountains, they prowled through a healthy mature subalpine forest filled with Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*). In the understory, their primary prey species of snowshoe hares and red squirrel were in abundance. When the reintroductions ended in 2006, over 200 lynx then resided in the national forest, and subsequent population surveys confirmed the lynx were reproducing and thriving.

Lynx wasn't the only species increasing in numbers in the Rio Grande National Forest though. The native spruce beetle (*Dendroctonus rufinpennis*) is a quarter-inch long

## SUMMARY

In Colorado, cumulative spruce beetle outbreaks over the past few decades have resulted in dead and dying spruce-dominated forests across state, private, and federal lands. Among the landscapes hardest hit is southern Colorado's Rio Grande National Forest; approximately 85 percent of the mature spruce comprising its subalpine forests has been killed by the beetles. These subalpine forests are critical to the persistence of the federally threatened Canada lynx reintroduced onto the forest beginning in 1999.

Because forest managers wanted to salvage the beetle-killed trees while minimizing negative impacts upon the population of Canada lynx, the Rio Grande National Forest asked John Squires, a research wildlife biologist with the Rocky Mountain Research Station's wildlife and terrestrial ecosystems program, to determine how lynx were using these beetle-impacted forests. Squires, in cooperation with researchers with Colorado Parks and Wildlife and Montana State University, outfitted 10 adult lynx with GPS collars to map how they navigated their home ranges.

The team found that despite the beetle outbreak significantly altering forest structure and composition, lynx still occupied these subalpine forests and were reproducing. At the home-range scale, Canada lynx selected forests with a high proportion of large-diameter beetle-killed trees. Within home ranges, lynx selected forest stands with a higher percentage of subcanopy live subalpine fir and Engelmann spruce, which provided the horizontal cover that snowshoe hares, the primary prey of lynx, sought during winter. Overall, Canada lynx preferentially selected forest stands composed of large-diameter and abundant beetle-killed trees with developed live Engelmann spruce-subalpine fir understories.

These findings were incorporated into the lynx habitat management direction in the recently adopted forest plan for the Rio Grande National Forest. Forest managers considering salvage in beetle-impacted forests are advised to locate salvage activities away from areas highly used by lynx and minimize the impact to the understory vegetation to maintain suitable lynx habitat. In high use areas on the Rio Grande, forest managers are directed to prioritize management activities in stands of little to no habitat value or that have little current value but good potential for promoting restoration of understory and lynx habitat.

*Lynx kitten on the Rio Grande National Forest 2015. USDA Forest Service photo.*

beetle with coloring ranging from dark brown to black and reddish-brown or black wing covers. Dead or injured spruce trees are both a food source and nursery for the beetles. Female beetles bore through the thick bark to reach the phloem, into which they deposit their eggs. If population levels increase to substantial levels, the beetles will attack healthy mature spruce trees and continue boring and munching through the forest. Their numbers only crash when winters are cold enough to kill the larva or the beetles run out of their food source.

In 2004, when Engelmann spruce began dying in the San Juan Mountains, it wasn't unexpected since spruce beetle outbreaks have been a historic disturbance agent in the southern Rocky Mountains. By 2007, 10 percent of the forest was beetle impacted. Subsequent annual aerial surveys revealed the beetles were impacting even more of the forest—20 percent in 2010 and 40 percent by 2014. By 2016, nearly 50 percent of what had once been ideal lynx habitat was now beetle killed. Many of the mature spruce that died had been growing for over 2 centuries.

"When I got here in 2005, everything in southwest Colorado for the most part was green and beautiful," says Jake Ivan, a senior scientist with Colorado Parks and Wildlife's mammals research section. "Shortly thereafter, the spruce beetle got going in our spruce-fir systems."

Randy Ghormley, the forest wildlife program lead on the Rio Grande National Forest prior to his retirement in 2018, recalls that "during the height of the outbreak you couldn't go out in the forest without bark beetles flying all over your face. Woodpeckers

## Canada Lynx in Colorado

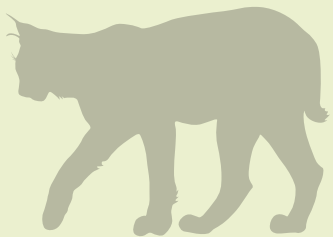
Canada lynx are found in the mature subalpine boreal-like forests found in states that include Washington, Montana, and Minnesota. Yet historically, their range may have extended south to the Greater Yellowstone Region and possibly to Colorado.

In these subalpine boreal forests, snowshoe hares are the primary prey of lynx, and both species are adapted to living in winter conditions that can last 6 months or more. Each species has a thick coat to ward off the cold and large paws that enable them to walk easily through the deep snow. A snowshoe hare's coat also turns white in the winter, allowing it to blend into the snow.

"One of the most interesting things about the lynx and snowshoe hare system is the morphological attributes and adaptations to living in deep snow environments," explains Joe Holbrook an assistant professor at the University of Wyoming. "But also, scientifically it's a system with deep roots in the field of ecology."

Canada lynx were thought to be extirpated from Colorado by the 1970s, probably due to a variety of factors, such as widespread predator control, unregulated trapping, and habitat changes in the early 20th century. The state of Colorado's Division of Wildlife (precursor to Parks and Wildlife), acting upon their mission to conserve native species in the state, planned a reintroduction effort that began in 1999 and ran until 2006, with 218 lynx released in total. Reintroduction sites were located in the Rio Grande National Forest due its high elevation spruce-fir forest having an abundance of hares, few roads, and about half of the forest designated as wilderness. Colorado Parks and Wildlife continues to monitor the lynx population. Lynx are also now known or suspected of using other national forests in the Rocky Mountain Region.

*During 1999–2006, 218 Canada lynx were reintroduced into the Rio Grande National Forest by the state of Colorado's Division of Wildlife. This location was chosen because of its availability of high elevation spruce-fir forests, which is the preferred habitat for Canada lynx and their prey of snowshoe hares and red squirrels. USDA Forest Service photo.*



couldn't keep up even though their populations were increasing."

Forest managers now faced a difficult decision of how to manage these beetle-impacted forests in the San Juan Mountains. Salvage logging would serve the dual purpose of removing dead trees to reduce the fuels load on the landscape and provide economic revenue for the nearby rural communities. Yet salvage could negatively impact the lynx, which the national forest had a charge to manage for as well. Another uncertainty was whether the lynx could survive in a forest whose overstory approached 100 percent mortality.

*A spruce beetle outbreak that began in 2004 resulted in nearly 50 percent of the overstory spruce trees being beetle killed on the Rio Grande National Forest. This drastically changed the forest structure, and land managers were concerned that the forest was no longer ideal lynx habitat. USDA Forest Service photo by John Squires.*

The Southern Rockies Lynx Amendment, a 2008 Regional Forester decision amending eight forest plans in the Rocky Mountain Region, provided direction to forest managers for how to manage habitat for lynx in live mature subalpine forests—not standing dead trees. "We didn't know what this changed condition meant for the lynx or its important food sources at such a large scale," Ghormley explains. "We knew they were out there, because we saw snow tracks and people had seen them occasionally."

In 2014, the Rio Grande National Forest invited researchers from the Rocky Mountain Research Station to participate in discussions on how the beetle-impacted forests would affect ecosystem services and wildfire risk. One of these researchers was John Squires, a research wildlife biologist with the Rocky Mountain Research Station's wildlife and terrestrial ecosystems program who specialized in studying the Canada lynx.

Ghormley says he pulled Squires aside to say that there were management questions regarding where to salvage with the least amount of impact upon lynx habitat and was John interested in finding the answers.

"There were staff who thought the San Juan Mountains were no longer lynx habitat because of the beetle outbreak," says Squires. "Knowing where lynx were could help silviculturists and forest managers identify the elements of these forested landscapes that are important to lynx, and then they can consider how to incorporate those areas into a management plan."

## Where Were Lynx Hunting?

This wasn't the first time Squires was asked to assist managers in the National Forest System to answer a lynx-management question. Several years earlier, he led a team comprised of Lucretia Olson, an ecologist with the Rocky Mountain Research Station, Elizabeth Roberts with the U.S. Forest Service, and Ivan to study how recreation users were affecting the lynx living in the San Juan Mountains and Vail Pass Recreation Area.

For this study, Squires and his team would again use GPS to track how lynx navigated the beetle-impacted forests during both the summer and winter. This team included Ghormley, Olson, and Ivan, as well as Rick Lawrence and Joe Holbrook, who at the time were with Montana State University.

From 2015 to 2017, they collected tracking data of 10 adults (6 males, 4 females) as they moved through their home range during the winter and summer. These winter datapoints would be particularly insightful, because winter is when snowshoe hares are especially vulnerable to predators. "They need to hide from everything, from goshawks, fox, coyotes, and lynx," explains Holbrook.

In a healthy subalpine forest, the mature trees have boughs that reach the ground and, in addition to cover provided by saplings, provide hiding places from the lynx. With the die-off of the overstory canopy, it became worrisome that the snowshoe hares had lost much of this vertical cover and were at risk in the beetle-impacted areas.

In all, the research team collected nearly 20,000 GPS locations. Within the home range, 735 plots were placed, where researchers collected vegetation data, such as tree height and diameter, volume of coarse wood debris, and horizontal cover to re-create the three-dimensional forest structure the lynx traveled through. They also determined the relative snowshoe hare density for each of the plots.

By analyzing differences in vegetative attributes between locations that lynx had traveled through and random, unused locations within their home range, researchers found that both the forests and lynx were resilient despite the severity of the beetle outbreak. "We found that hares were still present in these study areas," Squires says, adding, "The horizontal cover that the hares needed wasn't coming from live mature trees. It was coming from the release of the understory."

*A Canada lynx instrumented with a GPS collar to study movements in spruce beetle-impacted forests. USDA Forest Service photo by Steven Sunday.*

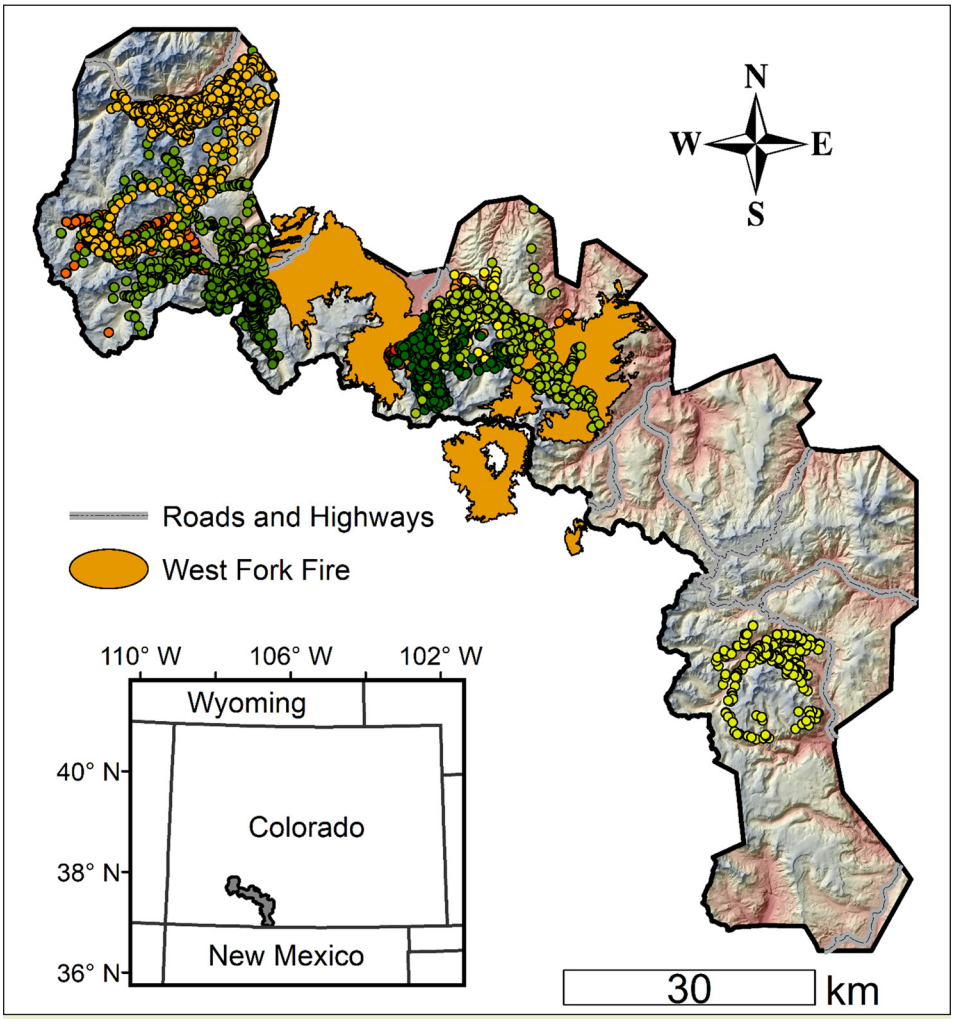
*"We found that hares were still present in these study areas. The horizontal cover that the hares needed wasn't coming from live mature trees. It was coming from the release of the understory, and it was released because of the high mortality of the overstory."*

–John Squires, USDA Forest Service Research Wildlife Biologist

During winter, Canada lynx selected areas with a higher canopy cover of live Engelmann spruce trees, larger live subalpine fir, and a higher density of small-diameter (7.6–12.4 cm [3–4.9 in.]) subalpine fir trees; during summer, in their home ranges lynx selected areas with larger dead subalpine fir and Engelmann spruce trees.

With overstory canopy now gone, the understory of subalpine fir, young spruce trees, and aspens claimed the growing space and were "growing like gangbusters," as Ghormley described it.

Why these young spruce remained untouched by the beetles is two-fold. "The younger trees' bark isn't thick enough to provide insulation through the winter, and they can also fight off the insects better," explains Ivan. "Wherever we have




*Canada lynx (*Lynx canadensis*) study area on the Rio Grande National Forest in southwestern Colorado, USA, with lynx GPS locations displayed (color of points changes with individual lynx). USDA Forest Service figure by John Squires.*

## KEY FINDINGS

- At the landscape scale, Canada lynx selected home ranges with a higher proportion of larger diameter, beetle-killed trees during winter and summer.
- At the home-range scale, lynx selected forests with high horizontal cover (mostly from conifer boughs touching the forest floor) across seasons. However, lynx exhibited seasonal differences in their use of beetle-impacted forests for other forest characteristics.
- During winter, Canada lynx selected areas with a higher canopy cover of live Engelmann spruce trees, larger live subalpine fir, and a higher density of small-diameter (7.6–12.4 cm [3–4.9 in.]) subalpine fir trees; during summer in their home ranges, lynx selected areas with larger dead subalpine fir and Engelmann spruce trees.

## Other Salvage Logging Resources

Bark beetle outbreaks aren't the only natural disturbances that result in standing dead forests. Wildfires do as well, and in the aftermath of these types of natural disasters, forest managers are faced with the decision of whether salvage logging is warranted. If so, how can they design the salvage projects to minimize the effects upon both wildlife and the landscape?

Researchers with the Rocky Mountain Research Station have conducted a number of studies that provide forest managers additional tools to assist in their decision-making. Here is a snapshot of some recent RMRS studies related to salvage logging:

**Of woodpeckers and harvests: Finding compatibility between habitat and salvage logging**

Research wildlife biologist Vicki Saab studies woodpeckers, a specifically disturbance-associated species whose habitats are post-wildfire landscapes. A study she conducted on the Malheur National Forest determined how the woodpeckers were using the post-wildfire landscape and where salvage logging could be conducted that would not impact the woodpeckers.

**Is that tree dead? Quantifying fire-killed trees to inform salvage and forest management**

Research ecologist Sharon Hood studies tree mortality following wildfires to identify characteristics of fire injuries that will result in tree death. Through her research over the past decade, she has improved the First Order Fire Effects Model (FOFEM), a modeling tool that forest managers can use to predict tree mortality and subsequently plan for salvage and other management activities.

**Post-spruce beetle timber salvage drives short-term surface fuel increases and understory vegetation shifts**

Research forester Mike Battaglia was part of a team who studied the effects of salvage logging on surface fuel loads and plant understory communities in high elevation Engelmann spruce (*Picea engelmannii*)-dominated forests. They found that surface fuels did increase in salvaged areas compared to untreated areas but expect over time surface fuels in untreated stands to increase to comparable or greater levels. Understory plant cover was reduced in salvaged areas due to shrub cover loss, but there was no difference in species diversity or richness between salvaged and nonsalvaged stands. The team recommended that salvage harvest effects be monitored over extended time frames to detect longer-term trends. See also www.fs.usda.gov/rmrs/projects/tree-regeneration-spruce-beetle-impacted-forests-central-colorado-0.

**Lynx and snowshoe hare response to spruce-beetle tree mortality: Evaluating habitat suitability and timber salvage in spruce-fir forests**

Since 2015, John Squires, an RMRS research wildlife biologist, has led a team of researchers and Rio Grande National Forest, Colorado Parks and Wildlife, and Montana State University collaborators to study the effects of spruce beetle outbreak on lynx habitat. Their current focus is on how to identify areas that can be salvage-logged without compromising the quality of lynx habitat. Stay tuned for new findings soon!

**Post-fire logging produces minimal persistent impacts on understory vegetation in northeastern Oregon, USA**

RMRS forester Erich Kyle Dodson collaborated with David Peterson, a research scientist with the Pacific Northwest Research Station, to study the long-term response of understory vegetation to two post-fire logging treatments in northeastern Oregon. The logging treatment was a commercial salvage logging with and without additional fuel reduction logging. Among their findings: Post-fire logging treatments produced no significant effects on understory vegetation cover, diversity, or community composition 15 years after treatment. Understory vegetation was seen to be resilient to postfire logging, particularly when best management practices, like logging over snow, is used to limit damage to soils and understory vegetation.

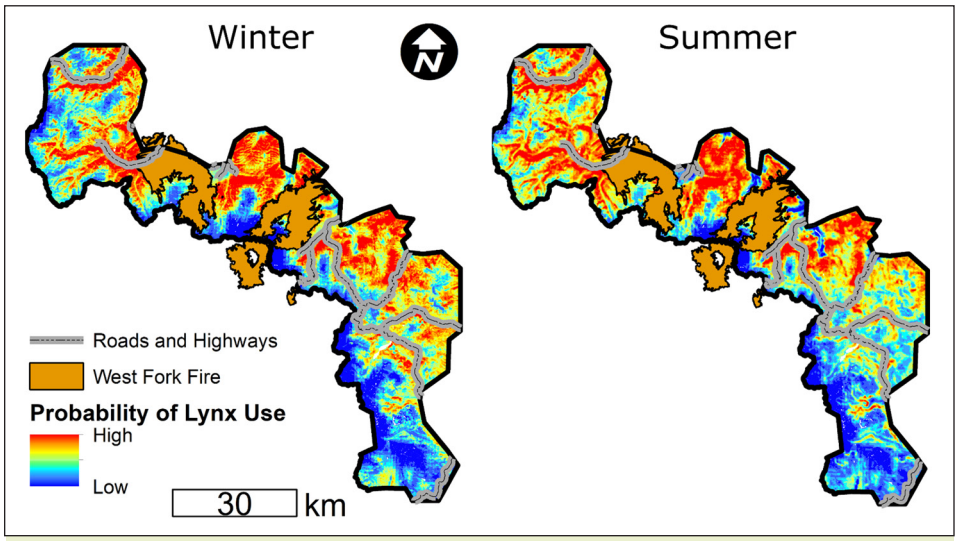
**Overlapping bark beetle outbreaks, salvage logging, and wildfire restructure a lodgepole pine ecosystem**

A team that included RMRS scientists Chuck Rhoades, research biogeochemist; Kristen Pelz, forester; and Paula Fornwalt, research ecologist, studied post-fire soil and vegetation responses in beetle-killed lodgepole pine (Pinus contorta) stands in Colorado. Some stands had recently been salvaged logged, which created an opportunity to compare salvage logging, wildfire, and the combination of logging followed by wildfire. Among their findings: Logging roughly doubled woody fuel cover while forb and shrub cover were reduced by half, and wildfire consumed all conifer seedlings in uncut and cut stands but did not stimulate conifer regeneration within 4 years of the fire. Salvage logging had mixed effects on tree regeneration, understory plant and surface cover, and soil nitrogen, but neither exacerbated nor ameliorated wildfire effects on those resources.

patches of young trees, they can be surrounded by brown forests."

The GPS locations revealed that the lynx hunted in patches now dominated by this understory, within stands characterized by large-diameter beetle-impacted trees, remnants of the forest that once was. At the landscape scale, Canada lynx selected home ranges with a higher proportion of larger diameter, beetle-killed trees during winter and summer.

At the home-range scale, lynx selected forests with high horizontal cover (mostly from conifer boughs touching the forest floor) across seasons. However, lynx exhibited seasonal differences in their use of beetle-impacted forests for other forest characteristics.




*From the GPS locations, the researchers created probability maps of lynx use in the study area. With these maps, land managers could conduct salvage in areas that would minimize the impact upon suitable lynx habitat. USDA Forest Service image.*

## Revising and Refining Management

Using their analyses, Squires and the team created predictive maps that identified lynx habitat within the greater landscape. With these maps, the Rio Grande National Forest identified areas where they could salvage log without decreasing the percentage of suitable lynx habitat. "While we knew the lynx were still using the forests, their maps refined the areas a little better," explains Kirby Self, the vegetation program manager on the Rio Grande National Forest.

"John's work is pretty ground-breaking in understanding lynx behavior, movements, and habitat use in that large beetle-disturbed landscape," says Peter McDonald, the regional program lead for the threatened, endangered, and sensitive species program for the U.S. Forest Service's Rocky Mountain Region. He adds, "It turned what we understood as lynx habitat on its head and was very instrumental to the forest developing its management direction for the forest plan, which also fed into their plans for their salvage program in that disturbed forest area on the Rio Grande."

Ivan says, "To their credit, the Forest Service had largely, where they could, did their salvage work in places that we identified as not as heavily selected by lynx and presumably hares."

On May 11, 2020, the forest supervisor for the Rio Grande National Forest signed the Record of Decision for the new forest plan. "This formally began the implementation of the new plan, including the new lynx habitat

### MANAGEMENT IMPLICATIONS

- Following high overstory mortality, understory regeneration provided the horizontal cover required by the snowshoe hare, one of the main lynx food sources.
- Canada lynx, in general, use areas of large-diameter, beetle-killed trees, which is important to consider when salvaging in lynx habitat.
- Impacts of salvage to lynx are reduced if forest subcanopy, especially subalpine fir, can be protected during tree removal.
- Canada lynx continued to disproportionately prefer areas in home ranges with abundant live spruce-fir trees, indicating the high value to lynx of remaining green tree patches within the beetle-disturbed landscape.

> *"This was a cool opportunity where science could provide some context to a real pragmatic on-the-ground issue. To me, that was most exciting piece of this research."*
>
> –Jake Ivan, senior scientist with Colorado Parks and Wildlife

management direction informed significantly by the results of John Squires' bark beetle response study," McDonald shared via e-mail.

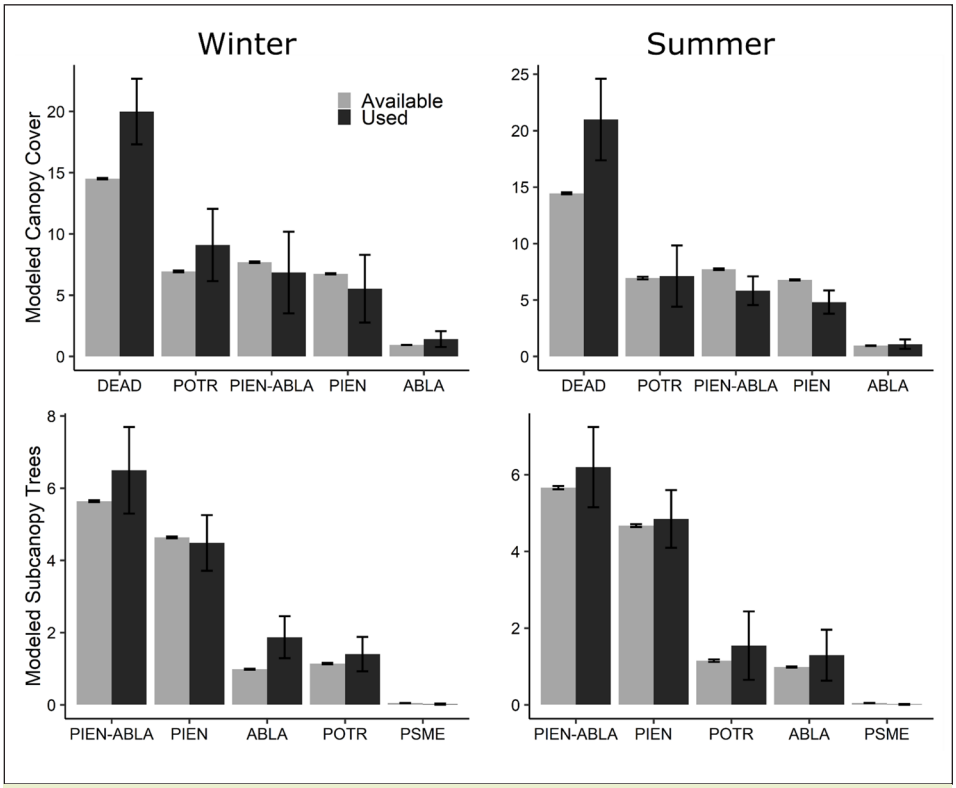
More emphasis is now placed on the importance of horizontal cover in lynx habitat rather than crown cover. Consequently, "We're encouraged to prescribe a silviculture prescription that increases horizontal cover over time," Self says.

The forest plan also has a new vegetation standard related to lynx management that was developed specifically for the Rio Grande based upon Squires' findings. "Vegetation standard 6 deals with minimizing [management] impacts on multistory spruce-fir stands, and we didn't have multistory much anymore," Ghormley explains. "We developed a vegetation standard 7, which is based on the response of lynx and hare to the changed conditions, primarily the understory conditions that we sampled. The intent was to have little to no impact on areas that met the new vegetation standard while directing and allowing more impact on areas predicted to have less use by lynx."

For the researchers, this outcome—their research informing management activities—is rewarding. "This was a cool opportunity where science could provide some context to a real pragmatic on-the-ground issue," explains Ivan. "To me, that was most exciting piece of this research."

## The Application of Research Elsewhere

As the beetles continue to move outside the Rio Grande National Forest and into neighboring spruce-fir forests that contain lynx populations, more forest managers will face the challenge of managing these changing landscapes. "There are neighboring forests that are obviously dealing with beetle kill issues and also coincidentally rewriting their plans at the same time as well," Ivan says. "We're actively working on figuring out how much of this research can carry over into these other forests. There are other researchers trying




*An analysis of the GPS tracking data revealed that lynx selected forests with large dead spruce and subalpine fir trees year-round. However, at the home-range scale, during winter lynx selected areas with a higher level of understory of Engelmann spruce and subalpine fir. Abbreviations: POTR, PIEN, ABLA, PSME, and DEAD indicate quaking aspen (*Populus tremuloides*), Engelmann spruce (*Picea engelmannii*), subalpine fir (*Abies lasiocarpa*), Douglas fir (*Pseudotsuga menziesii*), and percent total tree mortality in the canopy, respectively. USDA Forest Service figure by John Squires.*

to take as much as they can from what we learned and apply that to other forests."

One finding applicable in other subalpine spruce-fir forests is promoting and maintaining the understory vegetation. "From a Canada lynx perspective, on the southern range periphery, habitat seems to be a bit different in terms of how we conceptualize it relative to the northern boreal forests," explains Holbrook. "Our work illustrates how important the understory can be for Canada lynx, which is something we have observed throughout the Rocky Mountains."

Investing in research to track how lynx are navigating their home ranges can also inform where salvage can occur that minimizes the impact upon lynx habitat and provides managers more flexibility in managing the overall landscape.

**Want to learn more about lynx? Check out these other research projects conducted by the Rocky Mountain Research Station.**

Fisher and Martens and Lynx, Oh My! Multiregional, Goal Efficient Monitoring of Mesocarnivores

Winter sports and wildlife: Can Canada lynx and winter recreation share the same slope?

Managing forests and forest carnivores: Canada lynx and forest mosaics

## FURTHER READING

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*Captured lynx were fitted with radio collars, allowing researchers to follow their movements and plot locations relative to snowmobilers, and backcountry and resort skiers. Photo courtesy of the Rocky Mountain Research Station, Northern Rockies Lynx Study. USDA Forest Service photo.*

## SCIENTIST AND MANAGER PROFILES

The following individuals were instrumental in the creation of this Bulletin.

**JOHN SQUIRES** is a research wildlife biologist for the Rocky Mountain Research Station in Missoula, Montana. He earned his M.S. and Ph.D. in Zoology from the University of Wyoming. His current research concerns the management and conservation of Canada lynx, wolverines, and other sensitive species, including multiscale evaluations of resource selection; forest carnivore movements and connectivity; factors affecting population viability; the effects of forest management, recreation, and other human-induced impacts on species persistence; developing detection and monitoring methods for forest carnivores; and determining the effects of climate change on lynx and wolverine. Connect with John at https://www.fs.usda.gov/rmrs/people/jsquires.

**JOSEPH HOLBROOK** is an assistant professor in the Haub School of Natural Resources and the Department of Zoology and Physiology at the University of Wyoming. He earned an M.S. in Range and Wildlife Management from Texas A&M University, and a Ph.D. in Natural Resources from the University of Idaho. His current research focuses on the ecology and conservation of large- and medium-sized carnivores, and their associated prey.

**JAKE IVAN** is a wildlife research scientist in the mammals research section of Colorado Parks and Wildlife in Fort Collins, Colorado. He earned an M.S. in Wildlife Biology from the University of Montana, and a Ph.D. in Fish, Wildlife, and Conservation Biology from Colorado State University. His current research interests include impacts of bark beetle outbreaks on lynx, snowshoe hares, and other wildlife; impacts of timber harvest on snowshoe hares; long-term population dynamics of snowshoe hares at the southern extent of their range; and large-scale monitoring of rare and elusive species.

**LUCRETIA OLSON** is an ecologist for the Rocky Mountain Research Station in Missoula, Montana. She earned her Ph.D. in Ecology and Evolution from the University of California Los Angeles. Her main research interests are using spatial and habitat modeling to better understand the distribution, connectivity, and habitat use of wildlife species. Her current projects include modeling distribution and habitat selection of forest carnivores (lynx and fisher) in Idaho, Colorado, and western Montana; habitat use and anthropogenic impacts on raptors in Wyoming; and impacts of wildfire on lynx in Montana. Connect with Lucretia at https://www.fs.usda.gov/rmrs/people/lucretiaolson.

**RANDY GHORMLEY** was the forest program lead on the Rio Grande National Forest prior to his retirement in 2018.

**PETER MCDONALD** is the threatened, endangered, and sensitive species program leader for the Rocky Mountain Region.

**KIRBY SELF** is the vegetation program manager on the Rio Grande National Forest.

## PROJECT COLLABORATORS

**RICK LAWRENCE,** Montana State University (retired)

## WRITER'S PROFILE

**ANDREA WATTS** is a science writer for the Rocky Mountain Research Station and the Pacific Northwest Research Station. In addition to working for the USDA Forest Service, she has written for the Society of American Foresters and several magazines. Her portfolio is available at https//wattsinthewoods.com, and she can be reached at andwatts@live.com.

About the

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The purpose of SYCU is to provide scientific information to people who make and influence decisions about managing land.


**Nehalem Clark**: Bulletin Editor / Science Delivery Specialist
nehalem.clark@usda.gov

**Jessica Brewen:** Bulletin Editor / Science Delivery Specialist
jessica.brewen@usda.gov


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